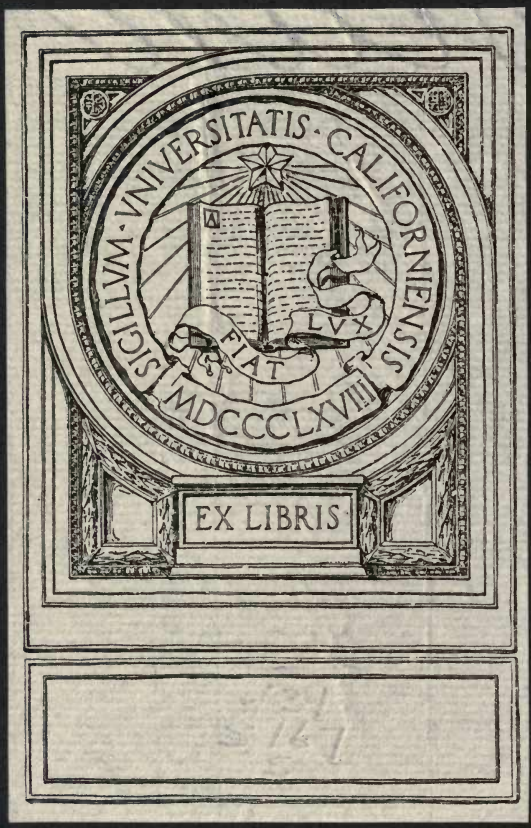

SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
LVX
FIAT
MDCCCLXVIII
EX LIBRIS

STUDIES IN GEOLOGY

A LABORATORY MANUAL BASED ON TOPOGRAPHIC MAPS AND FOLIOS OF THE UNITED STATES GEOLOGICAL SURVEY, FOR USE WITH CLASSES IN PHYSIOGRAPHIC AND STRUCTURAL GEOLOGY

BY

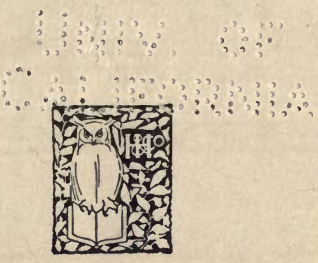
ROLLIN D. SALISBURY

THE UNIVERSITY OF CHICAGO

AND

ARTHUR C. TROWBRIDGE

THE UNIVERSITY OF IOWA



NEW YORK

HENRY HOLT AND COMPANY

1912

THE · MAPLE · PRESS · YORK · PA

PREFACE

This manual is a combination of the exercises now in use in the laboratories of the authors, with students of somewhat advanced grade. It is offered to teachers and students in the belief that a clear understanding of topographic maps contributes in an important way to a thorough knowledge of Physiography and physiographic geology, and that the use of these maps should be carried far enough to make them almost as familiar as the printed page. It is hoped that the manual may be useful to students who are under the direction of teachers who are familiar with modern methods of laboratory work in physiography and physical geology, as well as to those who are not so fortunate. The subject involved is not inherently difficult and may be mastered by any serious student, whether he be pupil or teacher, or altogether independent of schools.

The work is based on topographic maps (and a few folios) of the United States Geological Survey, and on a key to the interpretation of topographic maps,[1] published by the same survey. It is intended for the use of students how have some knowledge of physiography, or who are sufficiently mature to take up the subject in a somewhat thoroughgoing way. It might well be used, for example, by students using Chamberlin and Salisbury's Geology, Vol. I (*Geologic Processes*) for a text. While the outline follows the general order of this text, it may be adapted to courses based on any other standard text of similar scope. This outline, based chiefly on topographic maps, is followed by another

[1] Professional Paper 60, U. S. Geol. Surv.

for students of similar grade based on folios of the U. S. Geological Survey, and intended for use in thorough-going courses on Historical Geology, such as those based on Volumes II and III of Chamberlin and Salisbury's Earth History.

The adaptation of this outline to the needs, the time, the laboratory facilities, and the amount of laboratory assistance available, must be left to the individual teacher, but two methods of procedure which have been used successfully are here outlined. (1) By the one method, the class is divided into sections of four students each. The assignment of an exercise is made, and the maps placed where the students may study them at their convenience. An hour for conference with the instructor, subsequent to the study of the maps, is assigned to each section. In these conferences, the topic illustrated by the maps assigned is discussed, in connection with the maps. After the conference, or in some cases before, designated questions are answered in writing, and the papers handed to the instructor for correction. (2) By the other method, definite laboratory periods are assigned, their duration and frequency being determined by the time and general plan of the course, and the degree of preparation of the students. All the work is done in the laboratory in the presence of the instructor or his assistants. The students work individually or in pairs, and receive help or criticism from the instructor on demand. The latter method is the more successful with younger students, where time, laboratory space, assistance, and supply of maps are sufficient; but the first is perhaps equally successful with advanced students. The laboratory exercise with the maps follows the class-room discussion of the topic involved.

One or two conferences, following the study of the maps by the students, to five hours of class-room work are recommended; but this ratio may be varied *ad libitum*. When practicable, it is much better to have the laboratory work follow the class-room discussion of the same topic immediately, rather than to have the laboratory work on certain fixed days.

One copy of each map for every six or eight students in the class is sufficient. The maps should be backed with cloth to avoid speedy destruction, though a few maps should be unbacked, for the sake of the printed matter on the back. In a few cases, too, important illustrative material appears on the back of the map, as in the case of the Crater Lake, Ore., sheet.

Should it be desirable to develop a course of study beyond that called for by this outline, the maps and charts listed at the end of each exercise are recommended as a basis.

Thanks are due Professors W. W. Atwood and H. H. Barrows for free use of laboratory outlines in which their work is represented.

STUDIES IN PHYSIOGRAPHY

EQUIPMENT

Topographic Maps[1]

ALABAMA
- Fort Payne

ARIZONA
- Bright Angel
- Diamond Creek
- Echo Cliffs
- Mt. Trumbull
- Parker
- San Francisco Mt.
- Tusayan

ARKANSAS
- Batesville
- Marshall
- Morrillton
- Mountain View

CALIFORNIA
- Bridgeport

CALIFORNIA
- Cayucas
- Cucamonga
- Haywards
- Honey Lake
- La Jolla
- Lassen Peak
- Marysville
- Maxwell
- Mt. Lyell
- Mt. Whitney
- Oceanside
- San Francisco
- San Jose
- San Mateo
- Shasta
- Shasta Special
- Sierraville
- Sutter

[1] These maps may be ordered from the Director of the United States Geological Survey, Washington, D. C. All except a few special and double sheets may be had for 3 cents each, if ordered in lots of 100 or more.

CALIFORNIA
- Tamalpais
- Yosemite

COLORADO
- Apishapa
- Denver
- Elmoro
- Leadville
- Mesa de Maya
- Montrose
- Mount Jackson
- Spanish Peaks
- Walsenburg

CONNECTICUT
- Hartford

FLORIDA
- Tsala Apopka
- Williston

IDAHO
- Bisuka
- Meadows
- Mountain Home

ILLINOIS
- Dunlap
- Elizabeth
- Hennepin
- Highwood
- La Salle
- Marseilles

ILLINOIS
- New Haven
- Tallula
- Wheaton

INDIANA
- Boonville
- Owensboro
- Patoka
- Princeton
- Toleston

IOWA
- Cordova
- Des Moines
- Durant
- Fairfax
- Marion
- Oelwein
- Savanna
- Waukon

KANSAS
- Anthony
- Burlingame
- Coldwater
- Dodge
- Emporia
- Fredonia
- Great Bend
- Kinsley
- Lakin
- Leavenworth

KANSAS
- Pratt
- Spearville
- Syracuse

KENTUCKY
- Dawson Springs
- Harrodsburg
- Jonesville
- Lockport
- London
- Princeton
- Saylersville
- Tell City

LOUISIANA
- Baton Rouge
- Donaldsonville
- Gibson
- Hahnville
- New Orleans

MAINE
- Castine
- Freeport
- Fryeburg
- Gray
- Portland

MARYLAND
- Antietam

MARYLAND
- Choptank
- Emmitsburg
- Flintstone
- Ocean City
- Pawpaw
- Prince Frederick
- Tolchester

MASSACHUSETTS
- Boston
- Falmouth
- Holyoke
- Marthas Vineyard
- Nantucket
- Provincetown
- Wellfleet

MICHIGAN
- Calumet Special

MINNESOTA
- Minneapolis
- Minnetonka
- St. Paul

MISSOURI
- Boonville
- Forsyth
- Fulton
- Glasgow
- Hermann

MISSOURI
- Independence
- Jefferson City
- Lexington
- Marshall
- St. Louis
- Tuscumbia

MONTANA
- Chief Mountain
- Hamilton
- Saypo

NEBRASKA
- Browns Creek
- David City
- Lexington
- North Platte
- Whistle Creek

NEVADA
- Hawthorne
- Silver Peak

NEW HAMPSHIRE
- Monadnock

NEW JERSEY
- Asbury Park
- Atlantic City
- Barnegat
- Cape May

NEW JERSEY
- Greenwood Lake
- Long Beach
- High Bridge
- Passaic
- Sandy Hook

NEW MEXICO
- Corazon
- Mt. Taylor

NEW YORK
- Brooklyn
- Cohoes
- Cooperstown
- Elmira
- Hammondsport
- Islip
- Kaaterskill
- Monticello
- Niagara
- Oak Orchard
- Palmyra
- Paradox Lake
- Penn Yan
- Phelps
- Rosendale
- Skaneateles
- Sodus Bay
- Staten Island
- Syracuse
- Tully

NEW YORK
- Watkins
- Weedsport

NORTH CAROLINA
- Lincolnton
- Mt. Mitchell
- Pisgah

NORTH DAKOTA
- Casselton
- Fargo
- Pingree

OHIO
- Cleveland
- Covington
- East Cincinnati
- Oberlin
- Uhrichsville
- West Cincinnati

OKLAHOMA
- Sallisaw
- Sansbois

OREGON
- Coos Bay
- Crater Lake Special
- Port Orford

PENNSYLVANIA
- Bellefonte
- Brownsville
- Delaware Water Gap

PENNSYLVANIA
- Erie
- Everett
- Fairview
- Foxburg
- Hamburg
- Harrisburg
- Masontown

SOUTH CAROLINA
- Abbieville
- Pickens

SOUTH DAKOTA
- Elk Point

TENNESSEE
- Knoxville
- Maynardville
- Morristown
- Standingstone

TEXAS
- Palo Pinto
- Uvalde
- Van Horn

UTAH
- Abajo
- Fish Springs
- Gilbert Peak
- Hayden Peak
- Henry Mountains
- La Sal

VIRGINIA
- Abingdon
- Fredericksburg
- Grundy
- Harpers Ferry
- Natural Bridge Special

WASHINGTON
- Chelan
- Glacier Park
- Methow
- Mount Stuart
- Stehekin
- Tacoma

WEST VIRGINIA
- Arnoldsburg
- Fayetteville
- Madison
- Peytona
- Point Pleasant

WISCONSIN
- Baraboo

WISCONSIN
- Briggsville
- Cross Plains
- Delavan
- Denzer
- Geneva
- Koshkonong
- Lancaster
- Madison
- Muskego
- Oconomowoc
- Racine
- St. Croix Dalles
- Stoughton
- The Dells
- Waterloo
- Wausau
- Whitewater

WYOMING
- Canyon
- Cloud Peak
- Grand Teton

Geologic Folios[1]

- Bristol, Va.
- Camp Clarke, Nebr.
- Chattanooga, Tenn.
- Franklin, W. Va.–Va.
- Kingston, Tenn.
- Livingston, Mont.
- Masontown–Uniontown, Pa.
- Norfolk, Va.
- Piedmont, W. Va.–Md.
- Pikesville, Tenn.
- Rome, Ga.

[1] These folios may be obtained from the Director of the United States Geological Survey, Washington, D. C., for 25 cents per copy.

Charts

Coast Survey Charts,[1] Nos. 19, 21, 103, 104, 105, 5100, 5143, 8089.

Lake Michigan Chart,[2] No. 5.

Maps and Models

Students should have free access to good maps of the United States, when working on the topographic maps. A good wall map, showing political boundaries and relief, and if possible a good relief model should be in the laboratory.

Reference Material[3]

The Interpretation of Topographic Maps, Salisbury and Atwood; Prof. Paper 60, U. S. Geol. Surv.[4]

The text-books used in the course.

Bull. No. 13, Illinois Geol. Surv.

Bull. No. V, Wis. Geol. and Nat. Hist. Surv.

Bull. No. XIII, Wis. Geol. and Nat. Hist. Surv.

Mono. XI, U. S. Geol. Surv.

Mono. II, U. S. Geol. Surv.

GENERAL DIRECTIONS

In the case of each set of maps assigned, observe the following general outline:

[1] These charts may be had of the Coast and Geodetic Survey, Washington, D. C.

[2] This chart may be had of the United States Northern and Northwestern Lake Survey, Washington, D. C.

[3] These materials for reference should be open to the students in the laboratory or near-by library at all times.

[4] This report may be had upon request to the Director of the United States Geological Survey, Washington, D. C., so long as it remains in stock.

1. Study with care all the maps assigned, according to the directions and questions presented with them.

2. In studying a map, notice at the outset:
   a) The location of the region represented.
   b) The contour interval.
   c) The horizontal scale.
   d) The date when the region was surveyed.

3. Be able (or try to be) to answer *all* questions of the outline, and answer *in writing* those marked *.

4. Make answers concise and to the point. In some cases a word will suffice, in others a sentence, and in still other cases, full and carefully written statements are needed.

5. After the corrected paper is returned, review the exercise *with the maps*, in order to see just where mistakes were made.

6. Keep the main physiographic provinces of the United States constantly in mind, and note the province to which each map-area studied, belongs. (See Exercise XVII.)

I. THE WORK OF THE WIND

I. ASSIGNMENT

a) *Topographic Maps*

Asbury Park, N. J.	Long Beach, N. J.
Barnegat, N. J.	North Platte, Neb.
Browns Creek, Neb.	Pratt, Kan.
Cape May, N. J.	Sandy Hook, N. J.
Dodge, Kan.	Spearville, Kan.
Great Bend, Kan.	Syracuse, Kan.
Kingsley, Kan.	Toleston, Ind.

Whistle Creek, Neb.

b) *Geologic Folios*

Camp Clarke, Neb. Norfolk, Va.

II. OUTLINE FOR STUDY

*1. Describe the dunes shown on the New Jersey sheets, as to

a) Distribution.
b) Size.
c) Shape.
d) Source of sand.

*2. a) Compare the dunes shown on the Barnegat sheet, with those on Sandy Hook (Sandy Hook sheet).

b) How are elongate dunes formed? Do they represent (possibly, probably, certainly,) a later stage of dune development than the more common hillock or mound type? Explain.

3. What possible explanation may there be for the mound type of dunes southwest of Holly Beach (Cape May sheet),

and the elongate dunes northeast of the same place? Is there any suggestion that the sandy bar southwest of Holly Beach is of more recent origin than that to the northeast?

4. a) Locate the dunes on the topographic map of the Norfolk folio; then consult the areal geology sheet.

*b) What is the height of the highest dune shown on the maps of this folio? (Determination to be as accurate as possible, and the amount of possible error to be stated.)

5. Explain the distribution of the dunes shown on the Syracuse sheet; on the Pratt sheet.

6. What sort of rock would you expect (How confidently?) to find directly underlying the surface of the dune area of the Pratt region? Why?

*7. Give a brief summary concerning the dunes of the Kansas region, indicating their height, shape, distribution, and source of sand.

8. Can you suggest any reason why the dunes of the Kansas region are, in general, higher than those of the Atlantic Coast?

*9. Work out and state a rule expressing the amount of possible error in reading differences in elevations of two points from contour maps, (a) when neither point is on a contour line, (b) when one of the points is on a contour line, (c) when both points are on contour lines. Illustrate from selected specific points on one of the maps of the assigned list.

10. Camp Clarke Folio:

a) On the topographic sheet, locate areas of sand dunes, and several topographic features probably not due primarily to the wind.

b) Test the conclusions of a) by reference to the Areal Geology Sheet.

c) The character of the Arikaree Formation? See pp. 2 and 3 of the folio text.

d) What is the source of the sand for the dunes?

e) Note the depressions among the dunes, shown by depression contours.

f) Study the illustration sheet for evidences of wind erosion. Explain the origin of Smokestack Rock.

g) Do you find any signs of wind erosion on the topographic sheet?

*11. What can be said of the probable source or sources of sand in Nebraska, as suggested by the Nebraska maps?

*12. Give several possible explanations for the formation of such depressions as are found among the dunes in the Kansas and Nebraska regions.

13. How could dunes be recognized in the field, after they are covered with vegetation?

14. Why are the dunes on the Pacific Coast not shown on the topographic maps?

15. Describe the general principles governing the distribution of sand dunes in the United States, so far as illustrated by these maps.

16. Loess deposits and the abrasive work of the wind cannot be illustrated satisfactorily on topograpic maps.

For more extended study, the following additional maps and folios are suggested:

Chappell, Neb., sheet.	Kingman, Kan., sheet.
Fire Island, N. Y., sheet.	Lakin, Kan., sheet.
Green Run, Md. sheet.	Scotts Bluff, Neb., folio.
Hutchinson, Kan., sheet.	Springfield, Colo., sheet.

II. THE WORK OF GROUND WATER

I. ASSIGNMENT

a) *Topographic Maps*

Jonesville, Ky.
Knoxville, Tenn.
London, Ky.
Maynardville, Tenn.
Morristown, Tenn.
Natural Bridge, Va.
Princeton, Ky.
Standingstone, Tenn.
Tsala Apopka, Fla.
Williston, Fla.

b) *Geologic Folios*

Bristol, Va.
Kingston, Tenn.

II. OUTLINE FOR STUDY

*1. Give exact locations of topographic features due to ground water, shown on each of these maps.

*2. a) Describe the sinks shown on the Standingstone sheet, as to depth, shape, size, and topographic position.

b) What sort of rock would you expect to find beneath them?

3. What may ground water have had to do with the formation of the basin of Tsala Apopka Lake (Tsala Apopka sheet)? Note the general topography of the region.

*4. Choose a map from the assigned list which shows "Karst" topography.

*5. Bristol Folio:

a) From the topographic map, locate and describe briefly the sinks.

b) Explain why the sinks occur only in parallel lines. In answering this, study the structure section sheet.

*6. a) Are limestone sinks more common in flattish regions, or in rough ones? Why?

b) In what stage of an erosion cycle would you expect limestone sinks to be more common?

*7. Work out in detail the probable history of "Grassy Cove" in the northwestern part of the area shown on the topographic map of the Kingston folio. Consult the geologic map and text of the folio.

*8. Study the Natural Bridge sheet for effects of the work of ground water.

a) Note the numerous sinks throughout the region.

b) Explain the peculiar valley of Cedar Creek in Short Hills (central rectangle).

c) From the map, trace the history of the Natural Bridge of Virginia.

THE WORK OF RUNNING WATER

III. STAGES OF VALLEY DEVELOPMENT

I. ASSIGNMENT

a) *Topographic Maps*

Abajo, Utah.
Bisuka, Idaho.
Bright Angel, Ariz.
Brownsville, Pa.
Canyon, Wyo.
Cross Plains, Wis.
Des Moines, Ia.
Dunlap, Ill.
East Cincinnatti, Ohio.
Elizabeth, Ill.
Elk Point, S. D.
Fargo, N. D.
Highwood, Ill.
Leavenworth, Kan.
Lexington, Neb.
Marshall, Mo.
Masontown, Pa.
Montrose, Colo.
Oak Orchard, N. Y.
Patoka, Ind.
Peytona, W. Va.
Tallula, Ill.
Uhrichsville, Ohio.
Waterloo, Wis.
Waukon, Ia.

II. OUTLINE OF STUDY

1. In what stages of development are the following valleys:
   a) Black Canyon (N. E. corner, Montrose sheet)?
   b) Valley of Kanawha River (N. E. corner, Peytona sheet)?
   c) Valley of Missouri River (Leavenworth sheet)?
2. The age of the valleys shown on the Fargo sheet? Why are they so crooked?
3. Give possible explanation for the abnormally shaped

valley of the Mississippi River, shown on the Waukon sheet.

*4. Account for the type of valley found in the Abajo region.

*5. Account for the great difference in the sizes of the valley shown on the eastern portion of the Dunlap sheet.

*6. From maps of the assigned list, other than those designated in earlier questions, select one valley in youth, one in maturity, and one in old age, and state why they were chosen. Locate these valleys precisely (by name of map, location on map, and name of valley).

*7. Draw cross-sections across the three valleys chosen in 6. Use a horizontal scale the same as that of the map, and a vertical scale of $\frac{1}{8}$ inch to 20 feet. State precise location of each cross-section.

*8. Not using valleys designated above, name five other youthful valleys shown on the maps, five mature valleys and five valleys in old age.

*9. Account for the great difference in the character of the valley of the Yellowstone River and its tributaries south of 44° 50′, on the Canyon sheet.

*10. How is the single conspicuous stream (Snake River) in the region about Bisuka to be explained?

11. What differences do the maps show between youthful valleys in plateaus and in plains?

*12. Compare and contrast the history of the valleys shown on the Highwood and Oak Orchard sheets.

13. Some of the maps show complete or nearly complete tributary river systems. Using such maps, compare briefly the topographies of the upper and lower portions of the same river basins. Study examples enough to warrant a generalization. *Make the generalization.

Additional material on valleys may be obtained from almost any topographic map, though obviously some maps are better than others for the illustration of this topic. The more recent maps are always more desirable than older ones. In addition to those of the assignment above, the following maps, published recently, show various stages in valley development, and may be used for further work on the subject:

Baton Rouge, La.
Bayou Sara, La.
Central City, Ky.
Covington, Ohio.
Cumberland, Ohio.
Franklin, Pa.
Hennepin, Ill.
La Salle, Ill.
Lincolnton, N. C.
Lockport, Ky.
Monticello, N. Y.
Natural Bridge, Va.
Ottawa, Ohio.
Oxford, Ohio.
Ravenswood, W. Va.
Ray, N. D.
Summerfield, Ohio.
Wyandotte, Ok.

IV. THE TOPOGRAPHIC DEVELOPMENT OF REGIONS BY STREAMS

I. ASSIGNMENT

a) *Topographic Maps*

Abbieville, S. C.
Anthony, Kan.
Arnoldsburg, W. Va.
Boonville, Ind.
Brownsville, Pa.
Burlingame, Kan.
Casselton, N. D.
Cleveland, Ohio.
Coldwater, Kan.
Covington, Ohio.
Dawson Springs, Ky.
Emporia, Kan.
Fargo, N. D.
Foxburg, Pa.
Fredonia, Kan.
Grundy, Va.
Henry Mountains, Utah.
Lancaster, Wis.
La Sal, Utah.
La Salle, Ill.
Lincolnton, N. C.
Madison, W. Va.
Marshall, Mo.
Maxwell, Cal.
Mount Mitchell, N. C.
Mt. Trumbull, Ariz.
New Haven, Ill.
Niagara, N. Y.
Oberlin, Ohio.
Owensboro, Ind.
Peytona, W. Va.
Pickens, S. C.
Pisgah, N. C.
Prince Frederick, Md.
Princeton, Ind.
Saylersville, Ky.
St. Croix Dalles, Wis.
Tell City, Ky.

II. OUTLINE FOR STUDY

*1. Choose five maps showing regions in a youthful stage of development, and state why they were chosen.

2. In what stage of erosion is the Niagara region?

*3. Draw a cross-section profile across the Fargo sheet along the parallel 46° 50′. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{8}$ inch = 20 feet.) Is this the profile of youth, maturity, or old age?

4. What are the various map evidences of maturity of topography?

*5. From the maps, choose one region which shows as nearly ideal maturity as possible, and list its essential characteristics.

6. Choose three other regions in maturity as shown by the maps.

*7. Which is in the later stage of development, the Prince Frederick region or the Brownsville region? Give reasons for your answer.

8. Why are the valleys deeper in the Mt. Mitchell region than in the Lancaster area?

9. Why are the valleys east of the Blue Ridge (Pisgah sheet), such as the valleys of Middle Saluda River and the upper part of South Saluda River, deeper than the valleys just west of the Blue Ridge?

*10. The stage of erosion shown by the Kansas sheets? Reasons?

11. Choose several regions represented on the maps which are in topographic old age, and from them work out the various map evidences of old regions.

*12. Draw a cross-section profile across the Princeton sheet along parallel 38° 25′. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{8}$ inch = 20 feet.) Compare this profile with that of question 3. What is the essential difference?

13. Describe briefly the general topography of (a) the Kentucky-Virginia region, (b) the Kansas region, and (c)

the South Carolina region, as shown by the maps of these states, setting forth features of similarity and difference.

*14. Which of the regions mentioned in 13 is most advanced in the present cycle of erosion?

*15. Would the difference in the stage of erosion alone account for the differences between the Anthony region, and the Grundy region?

*16. Classify ten of the maps of the assigned list, which have not been used in answering any of the questions above, as to the stage of erosion they show.

17. What features in the area shown on the St. Croix Dalles sheet are not due to stream erosion? How does the topography shown on the greater portion of this map differ from a normal erosion topography?

*18. Is a larger proportion of the surface of a region available for agricultural purposes, in youth, maturity, or old age? Consider both regions of slight and of great relief. Find illustrations on the maps supporting your answer.

19. Note the location of common roads, railroads, towns, and general density of population in the several regions. Has the stage of erosion any influence on the above?

20. a) Compare the region shown on the Arizona sheets with that on the Ohio sheets, as to the stage of erosion.

b) What are the main differences between the topographies of the two regions? Explain the differences.

The following sheets show the various stages of erosion well, and may be made the basis of further work:

Anson, Tex. 31	Cataldo, Id.
Bidwell Bar, Cal.	Columbiana, Ala.
Burlington, Kan.	Corazon, N. M.
Butler, Mo. 34	Cranberry, N. C.

Caldwell, Kan.
Cumberland, Ohio.
Danville, Ill.–Ind.
Delphos, Ohio.
Dublin, Ohio.
Elizabeth, Ill.
Fayetteville, W. Va.
Forsyth, Mo.
Hennepin, Ill.
Leavenworth, Kan.
Marseilles, Ill.
Masontown, Pa.
Maumee Bay, Ohio.
Cross Plains, Wis.
Mt. Pines, Cal.
New Harmony, Ind.
Oxford, Ohio.
Palmyra, Mo.
Ray, N. D.
Rochester, N. Y.
Sansbois, Ok.
Summerfield, Ohio.
Tallula, Ill.
Tarboro, N. C.
Uhrichsville, Ohio.
Vermilion, Ohio.
Wartburg, Tenn.

V. THE INFLUENCE OF INEQUALITIES OF HARDNESS AND ROCK STRUCTURES ON EROSION TOPOGRAPHY AND STREAM ADJUSTMENT

I. ASSIGNMENT

a) *Topographic Maps*

Antietam, Md.
Boonville, Ind.
Bright Angel, Ariz.
Cucamonga, Cal.
Denver, Colo. 40
Fort Payne, Ala.
Hamburg, Pa.
Harrisburg, Pa.
High Bridge, N. J. 40
Holyoke, Mass. 40
Jonesville, Ky.
Kaaterskill, N. Y.
Lancaster, Wis.
Mesa de Maya, Colo.
Monadnock, N. H.
Mountain Home, Idaho.
Mt. Taylor, N. M.
Patoka, Ind.
Niagara, N. Y.
Saypo, Mont. 41
Sutter, Cal.
The Dells, Wis.
Uvalde, Tex. 41
Walsenburg, Colo.

b) *Geologic Folios*

Bristol, Va.
Franklin, W. Va.–Va.
Livingston, Mont.
Piedmont, W. Va.
Rome, Ga. 42

II. OUTLINE FOR STUDY

*1. Draw a diagram showing the attitude of the strata between Golden and Denver (Denver sheet), across South Table Mountain.

*2. Make a comparative study of the arrangement of the drainage lines on the Lancaster and Saypo sheets. Explain the differences.

*3. a) Explain the conditions of rock hardness and rock structure shown on the Niagara sheet.

b) The possible origin of the cliff through Queenston and Lockport?

c) Outline the history of Niagara Falls in as much detail as may be from the map.

d) Under what conditions would Lake Erie be drained by Niagara River as the falls continue to recede?

4. The origin of Sherrill Mound (S. central rectangle) and Sinsinawa Mound (S. E. corner), Lancaster sheet?

5. What is the significance of the fact that the Mumford Hills (Patoka sheet) have the same elevation as the high land southeast of them?

*6. Draw a cross-section of the Susquehanna valley at the first narrows above Harrisburg (Harrisburg sheet), and another two miles below the narrows. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{2}$ inch = 50 feet.) Interpret these sections.

7. Choose two areas shown on the assigned maps where the underlying rocks are probably massive.

*8. Does topography developed by erosion give (In all cases? In some cases?) the data necessary for determining structure? How? Illustrate by determining inferentially the structure of ten regions shown on the maps. Give reasons.

9. Rome folio:

*a) Show with drawings how the direction of dip of tilted beds may be determined from the topographic sheet.

b) In what direction do the strata of which Taylor

Ridge (N. W. and N. central rectangles) is composed, probably dip?

c) The probable structure between Simms Mountain and Lavender Mountain?

d) Test conclusions of b) and c) by reference to section BB of the structure section sheet.

e) From the topographic map, determine the probable origin of Gaylor Ridge (W. central rectangle). According to the historical geology sheet, are the rocks which make up this ridge of such a character as to resist successfully the processes of erosion? See also section CC of the structure section sheet.

f) Study other ridges and valleys of the topographic map in connection with data given on the historical geology and structure section sheets.

g) Note the numerous faults shown on the historical geology and structure section sheets. Could their presence have been detected from the topographic map alone?

10. Note the relation between valleys and faults as shown on the geologic map of the Livingston folio. See also Iddings, *Jour. Geol.*, Vol. 12, 1904, pp. 94–105.

*11. a) What structure is suggested by the topography of the region between Pine Mountain and Cumberland Mountain, Jonesville sheet?

b) Is further adjustment of streams likely to occur in the southeastern part of this area?

12. What structure will explain the curving form of Cushetunk Mountain, High Bridge sheet?

13. Piedmont folio:

a) From the topographic sheet, determine whether the strata are horizontal or tilted. If different in different parts, state the facts.

b) Test the conclusion arrived at in a) by reference to the areal geology and structure section sheets.

c) On the topographic sheet, find features which seem to be due to rocks harder than their surroundings.

d) From the areal geology sheet, see what sort of rock makes the features designated in c), and what kinds of rock are adjacent to it.

e) Is it possible to tell from the topographic sheet in what directions the various strata dip?

f) As shown on the areal geology sheet, do the main streams flow parallel with the folds, or at right angles to them?

g) Are the main valleys located on the synclines or on the anticlines (see structure sections)? Explain why this should be so.

14. a) Study the various maps of the Franklin and Bristol folios for the various influences of unequal resistance of rocks and rock structures on erosional topographies and on stream adjustment.

b) As seen on the structure section sheet (Franklin folio), is the Stc formation resistant or non-resistant to erosion? From the legend of the areal geology sheet, note the character of the rock of this formation.

*15. On each map of the assigned list, find topographic features which may be referred primarily to inequalities of hardness. This includes depressions as well as elevations.

16. How may elevations due to superior hardness of rock be distinguished from elevations of other origin, *e.g.*, volcanic cones? To what sorts of cases is your answer applicable?

17. At what stage in the development of an erosion cycle are outcrops of hard rock most conspicuous topographically?

Further work on the subjects considered in this exercise may be based on the following maps:

Abajo, Utah.
Abingdon, Va.
Bellefonte, Pa.
Bisuka, Idaho.
Cumberland Gap, Ky.
Delaware Water Gap, Pa.
Elizabethtown, N. Y.
Elmoro, Colo.
Emmitsburg, Md.
Everett, Pa.
Flintstone, Md.
Fort Collins, Colo.
Hollidaysburg, Pa.
Loon Lake, N. Y.
Loveland, Colo.
Monticello, N. Y.
Morrillton, Ark.
Natural Bridge, Va.
Sallisaw, Ok.
Sansbois, Ok.
Passaic, N. J.

VI. CYCLES OF EROSION

I. ASSIGNMENT

a) *Topographic Maps*

Antietam, Md.
Arnoldsburg, W. Va.
Batesville, Ark.
Bellefonte, Pa.
Delaware Water Gap, Pa.
Boonville, Ind.
Bright Angel, Ariz.
Corazon, N. M.
Echo Cliffs, Ariz.
Elizabeth, Ill.
Everett, Pa.
Forsyth, Mo.
Hamburg, Pa.
Harrisburg, Pa.
Harrodsburg, Ky.
Holyoke, Mass.
Lockport, Ky.
Marshall, Ark.
Mountain View, Ark.
Mt. Taylor, N. M.
Palo Pinto, Tex.
Passaic, N. J.
Pawpaw, Md.
Sallisaw, Ok.
Sansbois, Ok.
San Francisco Mt., Ariz.
Tusayan, Ariz.
Tuscumbia, Mo.
Wausau, Wis.
Walsenburg, Colo.

II. OUTLINE FOR STUDY

*1. Account for the marked difference in the upper and lower portions of the valley of the Little Colorado, San Francisco Mt. and Echo Cliffs sheets. Draw a profile

to scale of the stream bed from "The Crossing" to the Colorado River. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{8}$ inch = 250 feet.)

*2. Draw cross-sections of the upper and lower portions of the valley of the Little Colorado. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{8}$ inch = 250 feet.)

3. a) Study the cliffs and terraces on the Bright Angel sheet for suggestions of more than one cycle of erosion.

b) Is it likely that all the terraces are due to uplift of the land? How many uplifts would be called for?

c) Is the most extensive terrace (forming rim of Granite Gorge) probably due to the rejuvenation of the stream by uplift?

d) What other explanations may there be for these terraces, besides successive uplifts?

*4. Is there any difficulty in distinguishing true intrenched meanders of a stream in the second cycle, from consequent crooks in the first cycle of erosion? How would the former differ from the latter? Apply the criteria to the Tuscumbia region; to Conondoquinet Creek, Harrisburg sheet; to the Arnoldsburg region; to Brazos River, Palo Pinto sheet.

5. Can you suggest any conditions which may have caused the Connecticut River, Holyoke sheet, to flow across the hard beds of the Holyoke Range, when a course a few miles to the west would have avoided them?

*6. Antietam sheet:

a) Strata horizontal or tilted?

b) The origin of the ridges?

c) Explain how Potomac River came to flow across the ridges.

d) Draw a profile, to scale, from Sharpsburg (northwest part of map) southeast to Petersville.

e) Interpret the above profile.

f) Name the evidences of more than one cycle of erosion shown on this map. Are they conclusive?

*7. Draw a profile along the meridian of 76° 50′ on the Harrisburg sheet. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{8}$ inch = 400 feet.)

*8. Give possible interpretations of the above profile.

9. What are the possible interpretations of the terraces shown on the mountain slopes of the Everett quadrangle?

*10. Using the Pennsylvania maps as types, work out the erosional history of this part of the Appalachian Mountain region in detail.

11. When in the erosional history of the Appalachian Mountains were the great notches, or narrows, developed?

12. How many cycles of erosion are shown on the Arkansas sheets, and how are they recognized?

*13. How many cycles of erosion are suggested by the topography shown on the Wausau sheet?

14. Work out the probable erosion history of the region around the Ditney Hills on the Boonville sheet.

*15. a) From the Elizabeth sheet, draw a cross-section profile through "o" of "Brown" (Brown School) (Sec. 5, T. 28 N. R. 4E.), and "M" of "Benton Mound" (W. Sec. 27, T. 28 N. R. 4 E.). (Horizontal scale, same as map; vertical scale, $\frac{1}{8}$ inch = 20 feet.)

b) After a careful study of the rest of the map and of the profile above, give more than one possible interpretation of the erosional history of the region.

c) How would you work in the field to discover the correct interpretation?

*16. What seems to have been the erosion history of the New Mexico region?

17. What is the probable history of the numerous mesas and buttes shown on the Tusayan quadrangle?

18. Work out the probable erosion history of the Oklahoma region, so far as illustrated by the Oklahoma maps.

19. What data beyond those furnished by the topographic maps would be needed for working out, with certainty, the erosion history of the regions shown on these maps?

20. Are topographic features not in any way connected with the history of erosion cycles likely to be mistaken for those which result from uplift? If so, what?

*21. What evidence would you look for in the field to prove the existence of an old base-level plain, or an ancient peneplain?

The maps given below show various evidences of more than one cycle of erosion, and may be used for further work on this subject:

Apishapa, Colo.
Dawson Springs, Ky.
Flintstone, Md.
Franklin, Pa.
Hancock, W. Va.
High Bridge, N. J.
Hollidaysburg, Pa.
Hummelstown, Pa.
Huntingdon, Pa.
Latrobe, Pa.
Lykens, Pa.
Madison, W. Va.
Mesa de Maya, Colo.
Nashville, Tenn.
Natural Bridge, Va.
Peytonia, W. Va.
Ravenswood, W. Va.
Somerville, N. J.
Versailles, Mo.
Wyandotte, Ok.

VII. STREAM PIRACY

I. ASSIGNMENT

a) *Topographic Maps*

Abingdon, Va.	Harpers Ferry, Va.
Bellefonte, Pa.	Kaaterskill, N. Y.
Canyon, Wyo.	Lancaster, Wis.
Emmitsburg, Md.	Meadows, Idaho.
Fayetteville, W. Va.	Mt. Jackson, Colo.
Flintstone, Md.	Natural Bridge, Va.
Fort Payne, Ala.	Saypo, Mont.

b) *Geologic Folios*

Chattanooga, Tenn.	Piedmont, W. Va.–Md.
Franklin, W. Va.–Va.	Pikeville, Tenn.

II. OUTLINE FOR STUDY

1. Describe a possible case of future piracy in the Canyon region.

*2. Work out in writing a rational explanation of the valley flats along the main and side streams just north of Dubuque, Lancaster sheet. The essential points are Couler Valley, Peru Bottoms, and the Little Maquoketa River.

*3. Describe two cases of piracy shown on the Kaaterskill sheet.

4. Show why conditions for piracy are favorable in the Saypo region.

*5. Find a "wind gap" in the Harpers Ferry region, and trace its history.

6. Pikeville folio:

a) Note the location of the Sequatchie River and its relation to the geology of the region.

b) Is it probable that the present course of the river is its original course? If not, how may its present course have been attained?

c) Is any change in its course likely to occur in the future?

d) What are the chances of the Sequatchie stealing water now flowing north into Caney Forks?

*7. Chattanooga folio:

Study the northwestern quarter of the topographic map for possible piracies not yet accomplished. Point out specific illustrations and give reasons why piracy is likely to take place. (Use geologic map, structure sections, and text.)

8. Piedmont and Franklin folios:

a) Study the drainage of the southeast quarter of the Piedmont topographic sheet, and the northeast part of the Franklin sheet down to the South Branch River.

b) Study the same area on the Areal Geology Sheet.

c) Read the text on "Topography and Drainage," p. 1, Piedmont folio.

*d) Point out the possibilities of future piracy in this area.

9. In what stage of erosion is piracy most likely to occur? Illustrate from several of the assigned maps which show regions in different stages of erosion.

10. Study the remaining topographic maps of the assignment for cases of piracy already accomplished or liable to be accomplished in the future.

The following topographic maps, most of which are of recent date, also show possible cases of piracy:

Antietam, Md.
Cranberry, N. C.
Fort Collins, Colo.
Franklin, Pa.
Grand Teton, Wyo.
Jonesville, Ky.
Loveland, Colo.
Montpelier, Idaho.
Peytonia, W. Va.
Ravenswood, W. Va.
Shoshone, Wyo.
Uhrichsville, Ohio.

VIII. STREAM DEPOSITION

I. ASSIGNMENT

a) *Topographic Maps*

Baton Rouge, La.
Boonville, Mo.
Bridgeport, Cal.
Cucamonga, Cal.
David City, Neb.
Donaldsonville, La.
Fish Springs, Utah.
Fulton, Mo.
Gibson, La.
Glasgow, Mo.
Hahnville, La.
Hawthorne, Nev.
Hermann, Mo.
Independence, Mo.
Jefferson City, Mo.
Lexington, Mo.
Lexington, Neb.
Lockport, Ky.
Marshall, Mo.
Marysville, Cal.
Montrose, Colo.
Morrillton, Ark.
Mt. Whitney, Cal.
New Orleans, La.
Parker, Ariz.
San Jose, Cal.
Savanna, Ia.
Sierraville, Cal.
Silver Peak, Nev.
St. Louis, Mo.
Tacoma, Wash.
Van Horn, Texas.
Watkins, N. Y.

II. OUTLINE FOR STUDY

1. What suggestions are there on the Fish Springs, Silver Peak, Sierraville, and Marysville sheets that the lowlands are covered with waste from the mountains?

*2. If the lowlands referred to in 1 are covered with loose material, how would you go to work in the field to determine

whether this material is of marine, lacustrine, or river origin? If lacustrine, how would you determine whether from fresh or salt water?

3. Explain the behavior of the streams on the lowlands, referred to in 1.

4. What distribution of coarse and fine material would be found in these lowlands if they are covered by material washed from the higher lands?

*5. Why are there only isolated fans on the east side of Owens Valley, Mt. Whitney sheet, while a piedmont alluvial plain has been formed on the west side?

*6. How do alluvial fans differ from ancient deltas?

7. a) Study the various deposits at the foot of the mountains shown on the Hawthorne sheet.

*b) How could it be told in the field from the deposits east and southeast of Walker Lake, whether that lake was formerly larger and deeper than now?

*8. Would a vertical section through the lowlands, Cucamonga sheet, just south of San Antonio Canyon, and everywhere equidistant from the foot of the mountains, show material of uniform coarseness? Reasons? How would the material of such a section compare with that of a section at right angles to the foot of the montains? Reasons?

9. Note the course of the washes below the mouth of Deer Canyon and Day Canyon, on the Cucamonga sheet. *Explain how this process aids in forming a piedmont alluvial plain.

10. Lexington sheet:

a) Explain the network of streams in the channel of the Platte River.

b) What is the probable explanation of the hills about six miles northwest of Lexington?

c) In view of the fact suggested by a), account for the high gradient of the Platte River.

11. Arrange the Missouri sheets, so as to show the continuous course of the Missouri River:

a) Is deposition now in progress? The evidence?

b) Is deposition going on more rapidly at the up-stream or the down-stream ends of the islands? Explain.

c) How are the various lakes on the flood plain to be accounted for?

*d) Evidences that the river has shifted its course? Where are other shifts likely to occur?

*e) In what ways may the general difference in width of the flood plain above and below Glasgow be accounted for?

f) Has the difference in topography, and the condition of the tributary streams above and below Glasgow, any bearing on the problem?

*g) Explain why the Wakenda, Grand, and Chariton Rivers flow parallel with the main after entering the valley.

h) Why are there fewer roads on the flood plain than on the upland?

i) Explain what determined the location of Miami, DeWitt, Cambridge, Glasgow, Saline City, Lisbon, and Arrow Rock.

12. a) Explain the extremely steep slopes of the walls of the valley of Kentucky River, Lockport sheet, not now touched by the river, such as those west of Polsgrove and east of Craddock Bottom.

b) Explain the curved cliff and flat east of Bethel Church (south central, and southeast rectangles).

*13. Explain the form and distribution of the higher land shown on the Louisiana sheets.

14. Note the alluvial deposits northeast from Nita Crevasse (Donaldsonville sheet).

*15. Draw a cross-section to scale along the parallel of 40° 5′, on the Donaldsonville sheet. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{8}$ inch = 20 feet.) Interpret the section.

16. Interpret the flat at the south end of Seneca Lake, Watkins sheet.

*17. What sort of deposit would you expect to find underlying the city of Tacoma, Tacoma sheet?

*18. Why does Wapato Creek flow independently to the sea in the valley of Puyallup River, Tacoma sheet?

19. Point out the various advantages commercially in the situation of Tacoma.

20. Examine the remaining flood plain maps of the assignment for illustrations of stream deposition.

Other maps which show well various phases of stream deposition are the following:

Atchison, Kan.	Lac des Allemands, La.
Bonnet Carre, La.	La Sal, Utah.
Cheniere Caminade, La.	Loveland, Colo.
Chico, Cal.	Montpelier, Id.
Cut-off, La.	Pasadena, Cal.
Durango, Colo.	Patoka, Ind.–Ill.
East Delta, La.	Paxton, Neb.
Fort Collins, Colo.	Portland, Ore.
Fort McKinney, Wyo.	Quarantine, La,
Fremont, Neb.	Ray, N. D.
Gothenburg, Neb.	Sacramento, Cal.
Grand Teton, Wyo.	San Antonio, Cal.
Hamilton, Mont.	San Bernardino, Cal.
Kansas City, Kan.	San Francisco, Cal.

San Luis, Cal.
Savanna, Ia.
St. Barnard, La.
Stromsburg, Neb.
Syracuse, N. Y.
Tarrytown, N. Y.
Three Forks, Mont.
Watrous, N. M.
Waukon, Ia.
Williamstown, N. C.

The following charts of the Mississippi River Commission[1] may also be studied to advantage in connection with stream deposition:

Sheets 9, 14, 19, 20, and 27.

Index Charts I, II and III.

The following Coast Survey Charts are also good: *Numbers* 190, 191, 192, 194, 195 (fit together), and 19.

[1] These charts may be had of the Mississippi River Commission, St. Louis, Mo.

IX. STREAM TERRACES

I. ASSIGNMENT

a) *Topographic Maps*

Bright Angel, Ariz.
Chelan, Wash.
Cleveland, Ohio.
Cohoes, N. Y.
Cordova, Ia.–Ill.
East Cincinnati, Ohio.
Elk Point, S. D.
Foxburg, Pa.
Harrisburg, Pa.
Hartford, Conn.
Hennepin, Ill.
La Sal, Utah.
Lockport, Ky.
Marseilles, Ill.
Mountain Home, Idaho.
Mt. Trumbull, Ariz.
Point Pleasant, W.Va.
St. Paul, Minn.
Waukon, Ia.
West Cincinnati, Ohio.

II. OUTLINE FOR STUDY

*1. Draw a cross-section to scale across the Illinois River valley, Marseilles sheet. How may the feature brought out in the diagram be explained?

2. a) What has probably been an important factor in locating Vermilion, on the Elk Point sheet?

b) Note and explain the location of Fulton and Clinton, Cordova sheet.

*3. Lake Chelan, Chelan sheet, probably was made chiefly by the erosive work of a glacier. It drains into Columbia River. Explain the formation of the terraces along the river.

4. Cleveland sheet:

a) The probable origin of the terrace on which the city of Cleveland stands?

b) The elevation of the area around Brooklyn? Same for the area 3–6 miles south of Brooklyn? Explain.

c) Notice the several terraces along the Cuyahoga River. What is the elevation of these terraces above the river? State possible causes for the terraces. What relation might there be between the terraces and different stages in the level of the lake?

d) Explain the isolated patch of terrace at Thornburg (central rectangle).

*5. Draw a cross-section from the 5000-foot contour on Smith Prairie, Mountain Home sheet, due southwest to the same elevation on the southwest side of the Boise River. Interpret the section.

*6. How many terraces are shown in the valley of the Connecticut River on the Hartford sheet? What are the heights of these terraces above the river?

*7. Compare and contrast the topography of the lands between 200 feet and 300 feet in altitude, Cohoes sheet, with the topography of the land above 300 feet. Why the differences? How might your hypothesis be tested in the field?

8. What becomes of the terraces of the Hoosic River, Cohoes sheet, when traced up-stream?

*9. Draw a profile from Mechanicsville, about six miles east northeast to the second "C" in word "Schaghticoke," Cohoes sheet. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{8}$ inch = 100 feet.)

*10. What is the probable origin of the terraces along the above profile?

11. What suggestions can you make for the terraces in the Grand Canyon, as shown on the Arizona sheets?

12. Trace out the relationship of the terraces of the main and tributary canyons in the Arizona sheets.

13. Explain the terraces of the Grand and Green Rivers in the La Sal region. What becomes of these terraces upstream?

14. Waukon sheet:

a) The probable origin of the stream terraces?

b) What seems to have determined the location of Lansing, Harpers Ferry, and Prairie du Chien?

15. Locate and interpret terraces on four maps of the assigned list, not designated in previous questions.

Stream terraces are also shown to good advantage on the following topographic maps:

Beaver, Pa.
Camas Prairie, Idaho.
Covington, Ohio.
Delaware Water Gap, Pa.
Diamond Creek, Ariz.
Fonda, N. Y.
Kaibab, Ariz.
Latrobe, Pa.
Mount Adams, Wash.
Newcastle, Pa.
Ottawa, Ill.
Oxford, Ohio.
Peytona, W. Va.
Ravenswood, W. Va.
Springfield, Mass.
Tallula, Ill.
Tarboro, N. C.
Urichsville, Ohio.
Wyandotte, Ok.

THE WORK OF GLACIERS

X. MOUNTAIN GLACIATION

I. ASSIGNMENT

a) *Topographic Maps*

Bridgeport, Cal.
Chief Mountain, Mont.
Cloud Peak, Wyo.
Cucamonga, Cal.
Gilbert Peak, Utah.
Glacier Peak, Wash.
Hamilton, Mont.
Hayden Peak, Utah.
Leadville, Colo.
Montrose, Colo.
Mount Stuart, Wash.
Mt. Jackson, Colo.
Mt. Lyell, Cal.
Mt. Whitney, Cal.
Shasta Special, Cal.
Yosemite, Cal.

II. OUTLINE FOR STUDY

1. Study all the maps of the assignment for the results of the work of valley glaciers in high mountains.

2. Notice the elevation necessary for present and past glaciation in different latitudes.

3. What are the various map evidences of the former greater extent of valley glaciers?

*4. Explain why the Sierra Nevada Mountains (Mt. Whitney and Bridgeport sheets) contain glaciers, and why the San Antonio Mountains (Cucamongo sheet) do not, and apparently never have.

5. Explain the distribution of the glaciers around Mt. Shasta, Shasta Special sheet.

*6. a) What types of glaciers are shown in the Shasta and Glacier Peak regions?

b) What evidences are there that the glaciers were once longer and more numerous than now in these regions?

*7. List *all* the evidences of the previous existence of valley glaciers in the Mt. Lyell region. (There are six or seven of them.)

8. Cloud Peak sheet:

*a) Select a valley on the Cloud Peak sheet as a type of stream valleys re-shaped by valley glaciers, and draw a cross-section of it to scale.

*b) Draw a profile from the crest of the divide at Mather Peak (east central rectangle) east and north down the bed of the tributary to the North Fork of Clear Creek. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{16}$ inch = 250 feet.) Interpret the profile.

c) Locate a hanging valley on the sheet.

9. Leadville sheet:

*a) Interpret the curving ridge just west of the Arkansas River, $2\frac{1}{2}$ miles west of Leadville.

*b) The probable origin of Twin Lakes?

*c) Locate a good cirque on the map.

d) Note the location and elevation of the cirques. Note the elevation of the rim above the cirques, and of the botton of the cirques. Note the profiles of the valleys which have cirques at their heads.

*e) Draw a profile of the bottom of Crystal Lake Gulch (southwestern part of sheet) from the south edge of the map to Lake Creek. (Horizontal scale, same as that of map; vertical scale, $\frac{1}{16}$ inch = 100 feet.) Interpret the profile and explain its origin.

f) About what elevation was necessary for glaciation in this region during the glacial period.

10. a) Explain the formation of the compound cirques in the Hayden Peak and Gilbert Peak regions.

b) How much of this region appears to have been above the ice during the glacial period?

*11. Why are depositional features not so noticeable on maps as those due to erosion?

The following maps may be used for further work on this topic:

Berners Bay, Alaska.
Browning, Mont.
Chief Mountain, Mont.
Colfax, Cal.
Coopers Lake, Mont.
Copper Mountain, Alaska.
Crandall, Wyo.
Dardanelles, Cal.
Dayton, Wyo.
Grand Teton, Wyo.
Ishawooa, Wyo.
Lake, Wyo.
Meadows, Idaho.
Mount Adams, Wash.
Shoshone, Wyo.
Silverton, Colo.
Skykomish, Wash.
Snoqualmie, Wash.
Telluride, Colo.
Unita, Utah.

XI. GENERAL GLACIATION

I. ASSIGNMENT

Topographic Maps

Boston, Mass.
Brooklyn, N. Y.
Delavan, Wis.
Durant, Ia.
Fryeburg, Me.
Geneva, Wis.
Gray, Me.
Greenwood Lake, N. J.
Islip, N. Y.
Koshkonong, Wis.
Lancaster, Wis.
Madison, Wis.
Marion, Ia.
Minnetonka, Minn.
Monadnock, N. H.
Muskego, Wis.
Oconomowoc, Wis.
Oelwein, Ia.
Palmyra, N. Y.
Paradox Lake, N. Y.
Sodus Bay, N. Y.
Staten Island, N. Y.
St. Croix Dalles, Wis.
Stoughton, Wis.
Waterloo, Wis.
Weedsport, N. Y.
Wheaton, Ill.
Whitewater, Wis.

II. OUTLINE FOR STUDY

*1. From the maps of the assigned list, select at least five regions where the dominant type of topography is due to ground moraine.

*2. Locate terminal moraine belts on at least five sheets.

3. Work out the main topographic differences between ground moraine and terminal moraine, using as a basis the maps selected in 1 and 2.

*4. Locate at least four areas which are inferred to be outwash plains. How could your inference be tested in the field?

5. Find drumlins on at least two sheets.

*6. Contrast the Wisconsin and the New York type of drumlins.

7. Account for the lakes and swamps in the Delavan-Geneva region.

8. Account for the lakes and swamps in the Paradox Lake region.

*9. Determine (inferentially) by topography, the direction of ice movement in the Paradox Lake, Islip, Palmyra, and Brooklyn regions. How could your inference be verified or disproven in the field?

10. The probable origin of Lake Minnetonka, Minnetonka sheet?

*11. Under what conditions does drift control the topography of a region? Illustrate by reference to maps showing regions where (a) drift controls the topography, and (b) where bed-rock controls the topography.

*12. Select examples of hills which may be kames, so far as their topography and surroundings are concerned.

13. Study the maps for examples of eskers and valley trains.

*14. Compare and contrast the Lancaster and Koshkonong areas as to their value for agricultural purposes. What conditions due to glaciation in the latter are (a) advantageous, and (b) disadvantageous to agriculture?

15. What indications of glacial erosion are shown on the maps? Give list of locations.

*16. Account for the difference in the topography of the northeastern and southwestern portions of the area shown on the Oelwein sheet.

*17. Select maps showing regions glaciated by one of the older ice sheets.

18. How would you distinguish in the field whether an area has been covered by the last, or by one of the earlier ice sheets?

19. To what extent is the topography of the following regions due to glaciation:

a) St. Croix Dalles.
b) Gray.
c) Marion.
d) Paradox Lake.

20. Locate as many types of glacial lakes as you can identify on the maps.

*21. Describe briefly what sorts of material you would expect to find at the following places:

a) West Hills (west part of Islip quadrangle)
b) Central Islip (central part of same area).
c) East Islip (4 miles south of central Islip).
d) Baker Hill (east central rectangle, Palmyra sheet).
e) In the sharp elevation $2\frac{1}{4}$ miles south by southwest of Palmyra, Whitewater sheet.
f) The ridge in south central Sec. 3, three miles northwest of Naperville, Wheaton sheet.

22. Enumerate all the features shown on the maps which indicate glaciation. Comparison of maps showing typical glacial topography, with the Lancaster sheet of the driftless area, will be helpful.

The following maps may be used for further study of the work of the continental ice sheet in the United States:

Baldwinsville, N. Y.
Brandon, Vt.
Brockport, N. Y.
Calumet Special, Mich.
Canada Lake, N. Y.
Canton, N. Y.
Cross Plains. Wis.
De Smet, S. D.
Des Moines, Ia.
Eastport, Me.

Elizabethtown, N. Y.
Elmira, N. Y.
Fulton, N. Y.
Geneva–Racine, Wis.
Harlem, N. Y.
Hennepin, Ill.
Huron, S. D.
La Salle, Ill.
Loon Lake, N. Y.
Massillon, Ohio.
Monticello, N. Y.
Morris, Ill.
Northville, S. D.
Orland, Me.
Peterboro, N.H.
Raquette Lake, N. Y.
Raritan, N. J.
Redfield, S. D.
Rochester, N. Y.
Santanoni, N. Y.
Shopiere, Wis.
Silver Lake, Wis.
Swan Island, Me.
Tipton, Ia.
Tonawanda, N. Y.
Waterloo, Wis.
Watertown, Wis.
Wilmington, Ill.
Wooster, Ohio.

XII. DRAINAGE CHANGES DUE TO GLACIATION

I. ASSIGNMENT

a) *Topographic Maps*

Chelan, Wash.
Cooperstown, N. Y.
Cordova, Ia.–Ill.
East Cincinnati, Ohio.
Elizabeth, Ill.
Elmira, N. Y.
Fairfax, Ia.
Hammondsport, N. Y.
Masontown, Pa. (See folio.)
Methow, Wash.
Minneapolis, Minn.
Monticello, N. Y.
Penn Yan, N. Y.
Phelps, N. Y.
Pingree, N. D.
Rosendale, N. Y.
Skaneateles, N. Y.
St. Paul. Minn.
Stehekin, Wash.
Syracuse, N. Y.
Tully, N. Y.
Watkins, N. Y.
West Cincinnati, Ohio.

b) *References*

Bull. 13, Ill. Geol. Surv.
Prof. Paper 60, U. S. Geol. Surv., Plates CX–CXIX.
Mono. XLI, Pl. III, U. S. Geol. Surv.
Masontown–Uniontown, Pa., folio.

II. OUTLINE FOR STUDY

1. Study the Cordova, Ia.–Ill. sheet for possible changes in drainage, in connection with Bull. 13, Ill. Geol. Surv.

2. Work out the probable effect of the ice on the drainage of the region shown on the Phelps, Hammondsport, and Penn Yan sheets.

*3. Pingree sheet:

a) To what extent is the James River Valley pre-glacial? Post-glacial? How sure are you of your answer?

b) Make hypotheses for the lower and more interrupted bluffs on the east side of James Valley near Jim Lake. Can the real explanation be determined with certainty from the map?

c) How may the streamless valleys shown on the map be accounted for?

4. Tully sheet:

a) Note the following features:

1) The convergence of all the valleys and tributary valleys toward the south.

2) The divide between north and south flowing streams at points $1\frac{1}{4}$ miles northwest of Apulia Station, and 2 miles northwest of Tully Center.

3) The northward flowing courses of Onondaga and Butternut Creeks.

*b) Draw a profile to scale from Cardiff (central rectangle) to Mud Lake.

*c) With the points in a) and the profile in b) in mind, and after a careful study of the rest of the map, give a rational account of the effects of the glacier on the drainage of this region.

5. The probable origin of Lake Chelan (Stehekin, Methow, and Chelan sheets)?

6. a) Fit together the East and West Cincinnati sheets, and read the discussion of the area on p. 63, of Prof. Paper 60, or in Mono. XLI, Pt. III, U. S. Geol. Surv.

*b) List the main events in the history of the region leading up to the present drainage system.

7. Work out the drainage change which has taken place

in the area shown on Plate CXIX, Prof. Paper 60, or see the Masontown–Uniontown folio.

*8. Minneapolis and St. Paul sheets:

a) Account for the discrepancy in size and stage of development between the valley of the Minnesota River, and the valley of the Mississippi River above Pike Island.

b) How explain the numerous lakes and marshes in the Minnesota and lower Mississippi valleys?

c) Why are there no lakes in the upper part of the valley of the Mississippi in this region?

d) Are St. Anthony Falls (northeast corner Minneapolis sheet) of post-glacial or pre-glacial origin? The same for Minnehaha Falls (southeast of Minneapolis, St. Paul sheet)?

e) Can you tell from the map whether the walls of the Mississippi gorge southeast of Minneapolis are of solid rock or of drift?

f) What basis is there in the recession of St. Anthony Falls from an original position at Pike Island, for an estimate of the time since the last glacial epoch?

9. Study the headwater region of Apple River, as shown in the northeast portion of the Elizabeth sheet, according to the outline below. Though this immediate district is in the driftless area, an abundance of old drift is found just east of the boundary of the quadrangle.

a) Note the continuity of the valleys occupied by South Fork and West Fork of Apple River.

b) Note the angle between the valley occupied by South and West Forks, and the main valley of Apple River at Millville.

c) Why is the valley of South Fork wider than that of West Fork?

d) Why does the valley of South Fork become wider to the southeast (up-stream)?

e) Why do some of the tributaries of South Fork form an acute angle with the main down-stream rather than up-stream?

f) Explain the canyon-like appearance of the valley of Apple River for several miles southwest of Millville, and the contrast between this valley and the valley of West and South Forks.

*g) Work out and state a possible drainage change in this area, which will explain the above-mentioned features.

*h) How would you investigate the area east of this region in the field, to prove or disprove your hypothesis?

*10. Work out in as much detail as possible two distinct cases of drainage change due to glaciation, not included in the preceding questions.

The cases outlined in the exercise above are only a few illustrations of hundreds of changes in drainage affected by the ice in the northern part of the United States. Some other maps which show various effects of glaciation on drainage are listed below:

Antwerp, N. Y.
Baldwinsville, N. Y.
Calumet Special, Mich.
Canton, N. Y.
Chief Mountain, Mont.
Delavan and Geneva Wis.
Dells, Denzer, Briggsville, and Baraboo, Wis. (See *Bull.* V, Wis. Geol. and Nat. Hist. Surv.)
Des Moines, Ia.
Elizabethtown, N. Y.
Ellsworth, Pa.
Franklin, Pa.
Fryeburg, Me.
Greenwood Lake, N. J.
Hennepin, Ill.
Oriskany, N. Y.
Snoqualmie, Wash.
Tower, N. D.
Waterloo, Wis.
Weedsport, N. Y.
Wyndmere, N. D.

XIII. SHORE-LINES

I. ASSIGNMENT

a) *Topographic Maps*

Atlantic City, N. J.
Barnegat, N. J.
Brooklyn, N. Y.
Calumet Special, Mich.
Cape May, N. J.
Castine, Me.
Cayucas, Cal.
Choptank, Md.
Coos Bay, Ore.
Erie, Pa.
Falmouth, Mass.
Fairview, Pa.
Freeport, Me.
Haywards, Cal.
Highwood, Ill.
Islip, N. Y.
La Jolla, Cal.
Marthas Vineyard, Mass.
Nantucket, Mass.
Ocean City, Md.
Port Orford, Ore.
Portland, Me.
Prince Frederick, Md.
Provincetown, Mass.
Racine, Wis.
San Francisco, Cal.
San Mateo, Cal.
Sandy Hook, N. J.
Sodus Bay, N. Y.
Tacoma, Wash.
Tamalpais, Cal.
Tolchester, Md.
Wellfleet, Mass.

b) *Cost Survey Charts:*
Nos. 19, 21, 103, 104, 105, 5100, 5143, 8089.

c) *Lake Michigan Chart* No. 5.

II. OUTLINE FOR STUDY

1. Account for the difference in the cliffs shown in the Fairview and Tamalpais quadrangles.

2. Find illustrations of erosional features on the shore-lines shown on the maps.

3. Locate illustrations of (a) bars, (b) spits, (c) hooks, and (d) barrier reefs, on at last three maps.

4. How have the bars, spits, hooks, and reefs located in 3, been built above high tide?

*5. Provincetown and Wellfleet sheets:

a) Work out the probable origin and history of Cape Cod. (To do this, study the general topography and the shore-line carefully.)

b) Account for the difference in the character of the coast on the east and west side of Cape Cod. Which side is in the later stage of development?

6. Explain in detail the horizontal configuration of the coast shown on the Port Orford sheet.

7. What effect do the waves have on the valleys between the shore and the Chicago and Northwestern Railroad, in the Highwood region?

*8. Racine sheet:

a) Work out a rational explanation for the peculiar course of Pike River.

b) Account for the narrow embayment in the north-western part of the city of Kenosha.

9. What is the source of the material of which Sandy Hook is made (Sandy Hook sheet)?

*10. How may Coatue and Coskata Beaches (Nantucket sheet) be accounted for? Work out an explanation of the "Points" (cusps) on the inner margin of Coatue Beach.

*11. On the assigned maps, find three shore-lines the form of which is due to submergence, and three due to emergence. Reasons.

*12. If the terms youth, maturity, and old age are to be

applied to shore-lines, in what stage of development would you put those shown on the (a) Tolchester, (b) Atlantic City, (c) Highwood, (d) Freeport, (e) Cape May, and (f) Fairview sheets?

*13. a) Select at least four maps where glaciation has affected the coast.

b) How has glaciation modified these coasts?

c) What other factors may have helped to determine the horizontal configuration of these coasts?

*14. Frame a hypothesis which might explain the origin and development of Presque Isle (Erie sheet) and its topography. (Do not neglect the wave-cut cliff bordering the bay on the south.)

15. Account for the peculiar course of Walnut Creek (Erie sheet) and the great variation in the character of the valley.

16. How may the broad flat lands bordering San Francisco Bay be accounted for? (Tamalpais, San Francisco, San Mateo, and Haywards sheets.)

*17. Does wave erosion straighten shore-lines, or make them irregular? Point out illustrations on maps of the assigned list.

*18. Does coast-deposition make coasts straight or irregular? Point out illustrations.

19. Is the effect of waves and shore currents to simplify or complicate shore-lines? Verify your answer from the maps.

20. What determines the rate of development of shore-lines? Cite illustrations from the maps.

*21. Describe in detail two shore-line regions of different types. In doing this, consider the following points:

a) Are the shore-lines due to deposition or erosion?

b) Are the islands of rock, glacial drift, or shore drift?

c) Has the coast been glaciated?

d) Has diastrophism affected the coast? If so, which phase of diastrophism?

e) What influence on the coast has the work of (1) wind, (2) rivers, (3) waves, (4) currents, (5) glaciers, and (6) organic agencies had?

f) Is the coast young, mature, or old?

g) The probable future of the coast?

Further study of the subject of shore-lines may be based on the following maps and charts:

a) *Topographic Maps*

Arroyo Grande, Cal.	Goleta, Cal.
Asbury Park, N. J.	Hamlin, N. Y.
Biddeford, Me. 71	Muskegat, Mass.
Boston Bay, Mass. 71	Northport, N. Y.
Copper Mountain, Alas.	Oceanside, Cal. 73
Deer Isle, Me. 67	Piney Point, Md.
East Delta, La.	Riverhead, N. Y.
Euclid, Ohio. 73	San Luis, Cal.
Ferry, Ohio.	Sandusky, Ohio.
Geneva-Racine, Wis.	Shelter Island, N. Y.

Stonington, Conn.

b) *Coast Survey Charts*

Nos. 110, 188, 201, 207, 210, 315, 5106, 5127.

XIV. DIASTROPHISM

I. ASSIGNMENT

a) *Topographic Maps*

Boston, Mass.
Castine, Me.
Choptank, Md.
Coos Bay, Ore.
Diamond Creek, Ariz.
Echo Cliffs, Ariz.
Erie, Pa.
Fairview, Pa.
Fish Springs, Utah.
Fredricksburg, Va.
Grand Teton, Wyo.
Hawthorne, Nev.
Honey Lake, Cal.
La Sal, Utah.
Mt. Trumbull, Ariz.
Mt. Whitney, Cal.
Oceanside, Cal.
Tolchester, Md.
Uvalde, Texas.
Van Horn, Texas.

b) *Geologic Folios*

Bristol, Va.
Franklin, W. Va.–Va.
Livingston, Mont.
Piedmont, W. Va.–Md.
Rome, Ga.

c) Coast Survey Chart No 5100.

d) *References*

Mono. XI, U. S. Geol. Surv.
Mono. II, U. S. Geol. Surv.

II. OUTLINE FOR STUDY

1. Name several coastal regions shown on the maps assigned, which appear to have sunk relative to sea level.

2. Select several shore-lines apparently due to emergence from the sea.

3. Do the raised shore-lines on the Erie and Fairview sheets necessarily mean diastrophism in this region? Explain.

4. a) Explain how glaciers may so modify a coast-line, as to make it appear to have sunk.

b) How can coast-lines due to sinking be distinguished from coast lines developed by glacial erosion, (1) on topographic maps, (2) in the field?

*5. Interpret the coastal area shown on the Oceanside sheet. The essential features are the cliffs and ridges back from the shore, the salt-water lagoons, and the varying character of the valley of the San Luis Rey River.

6. Interpret the coastal region of the Coos Bay quadrangle, so far as due to diastrophism.

*7. What seems to have been the origin of Honey Lake (Honey Lake sheet)? (For discussion of this point, see Russell, Mono. XI, U. S. Geol. Surv., p. 25 and Plate III.)

8. Mt. Trumbull and Diamond Creek sheets:

a) Study for evidences of faulting. (See the general account of this region by Dutton, in Mono. II, U. S. Geol. Surv.)

b) The probable origin of Grand Wash Cliffs and Hurricane Ledge? Note the relation of these features to each other.

c) How could the date of faulting in this region be determined in the field?

d) Why is the Grand Canyon east of the Grand Wash Cliffs deeper than it is west of the cliffs? Bring out the influence of faulting on the formation of the Grand Canyon.

e) Explain the asymmetric appearance of the valley south of Pierce Ferry (southwest rectangle, Mt. Trumbull sheet).

*9. How, otherwise than by faulting, might Echo Cliffs, Echo Cliffs sheet, be accounted for?

*10. How could the presence or absence of faults along the scarps shown on the Honey Lake, Mt. Trumbull, and Echo Cliffs sheets be proved in the field?

11. Locate features which are probably fault scarps on at least three sheets not designated in previous questions.

*12. Give several possible explanations for the highlands in the north and northwest parts of the Uvalde region, and the lowlands in the rest of the area shown on the map.

*13. Study the structure sections of the Rome, Bristol, Piedmont, and Franklin folios, for folds and faults brought about by diastrophism.

a) Are these features the result of tension or pressure?

b) In what direction were the forces applied?

c) What influence has diastrophism had in the formation of the topography of these regions?

d) The faults are all of the same type; are they normal or reversed?

e) What is the probable fundamental factor in the origin of forces which develop such folds and faults as are shown in these sections?

*14. Explain the several terraces on the south side of San Clemente Island (Coast Survey Chart No. 5100) and their absence on the north side. Notice in this connection the depths of the water around the island.

For further study of the topographic results of various phases of diastrophism, see the following maps:

Delaware Water Gap, Pa.	Fort Payne, Ala.
Fish Lake, Utah.	Granite Range, Nev.
Fort Collins, Colo.	Hamilton, Mont.
Fort McKinney, Wyo.	Hinsdale, Mont.

La Jolla, Cal.
Loveland, Colo.
Meadows, Idaho.
Montpelier, Id.
Piney Point, Md.
Sacramento, Cal.
San Luis Rey, Cal.
St. George, Utah.

Sheet 3, Atlas of the Tertiary History of the Grand Canyon District, U. S. Geological Survey.

XV. VULCANISM

I. ASSIGNMENT

Topographic Maps

Crater Lake, Ore.
Elmoro, Colo.
Henry Mountains, Utah.
Holyoke, Mass.
Honey Lake, Cal.
La Sal, Utah.
Lassens Peak, Cal.
Marysville, Cal.
Monadnock, N. H.
Mount Taylor, N. M.
Mt. Lyell, Cal.
Mt. Whitney, Cal.
San Francisco Mt., Ariz.
Shasta, Cal.
Spanish Peaks, Colo.
Uvalde, Texas.
Walsenburg, Colo.

II. OUTLINE FOR STUDY

1. What are the various map evidences of the previous existence of volcanoes? Of lava intrusions?

*2. Locate volcanic cones on two maps, and state whether they are probably made of lava or cinders.

*3. Distinguish, as far as possible, between lava cones and laccoliths on the maps. Use several illustrations, and state reasons for your conclusions.

4. What were the parts of vulcanism and of diastrophism respectively, in the making of Crater Lake (Crater Lake sheet).

*5. Spanish Peaks sheet:

a) The probable origin of the high lands around West Spanish Peak?

b) The probable origin of the discontinuous linear elevations radiating outward from West Spanish Peak?

c) Is the igneous rock of this district harder or softer than its surroundings?

*6. Draw a diagram showing the structure which permits the sill forming the Holyoke Range (Holyoke sheet) to outcrop as it does.

7. To what extent have the features of these maps due to vulcanism been modified by erosion?

*8. Mt. Taylor sheet:

a) The origin of the San Mateo Mts.?

b) Give several possible explanations for the small conical hills south and southwest of Miller P. O.

9. Note the lakes shown on the central and east central portions of the Lassens Peak sheet. They are for the most part not of glacial origin. How may they have originated?

10. What conclusion can be reached from the Mt. Lyell sheet, as to the age of the Mono Craters?

*11. a) Are features directly due to vulcanism likely to be confused on the maps with those of other origin? Compare Monadnock Mountain (Monadnock sheet) with Mt. Shasta (Shasta sheet).

b) What part may vulcanism have played in the making of Monadnock Mountain?

12. How has vulcanism affected the topography of the Elmoro and Walsenburg regions?

Though vulcanism is not well illustrated on topographic maps, the following maps, in addition to those assigned, show direct effects of vulcanism:

Abajo, Utah. Terlingua Special, Texas.
Modoc Lava Beds, Cal. Trinidad, Colo.
Mount Adams, Wash.

XVI. SPECIAL STUDY OF THE BARABOO REGION, WISCONSIN

The region around Baraboo, Wisconsin, shown on the four maps of the assignment, is exceptionally rich in geologic phenomena. Though detailed work in the field is necessary before all the complicated history can be ascertained, still many important features can be worked out from the topographic maps, to varying degrees of certainty. The questions below are asked with a view to bringing out the history of the region only so far as it can be interpreted from the maps. Any one of many other regions might have been chosen for such a study, the Baraboo region being selected for present uses chiefly because it is well known to the authors and to some of their students.

I. ASSIGNMENT

a) *Topographic Maps*

Baraboo, Wis. Denzer, Wis.
Briggsville, Wis. The Dells, Wis.

b) *References*

Professional Paper 60, U. S. Geol. Surv., Pl. CXX and pp. 64, 65.

Bulletins Nos. V and XIII of the Wisconsin Geological and Natural History Survey are reports on this region and may be used for reference if they are available.

II. OUTLINE FOR STUDY

1. Note the location of the region and its boundaries.

2. Note the location of this region with reference to that of the "Driftless Area."

3. Point out the most conspicuous topographic features of the region.

4. Does drift or bed-rock control the larger features of the topography?

*5. Point out topographic features due to bed-rock; due to drift.

*6. What may have given rise to the ridges on opposite sides of the valley of the Baraboo River, in the central part of the region? These ridges are known as the North and South Ranges, respectively.

7. Give a possible explanation for the fact that the south side of the South Range is steeper than the north side.

8. Can you suggest any reason why the North Range should be narrower than the South Range?

9. Are the rock strata horizontal or tilted in the area around Leland and Denzer on the Denzer sheet, and north of Reedsburg and west of Kilbourn on The Dells sheet?

*10. What inferences can be drawn as to the structural and age relations between the different formations of the region, in view of your answers to questions 6 and 9?

11. In what topographic feature does the hardest rock of the region probably show itself?

12. The probable origin of Elephant's Back ($3\frac{1}{2}$ miles north of Kilbourn, on The Dells sheet)?

*13. Give a possible explanation for the several flats at about 1400 feet elevation on the South Range, as $3\frac{1}{2}$ miles north by northeast of Denzer, 4 miles southeast of North Freedom, and just east of Devils Lake.

*14. The Baraboo Narrows, the gap in which Devils Lake lies, and the Narrows of the Baraboo River at Able-

man, are of pre-glacial origin. The present course of the Wisconsin River from the upper end of The Dells to Prairie du Sac (Baraboo sheet) is clearly post-glacial. Study the three gaps mentioned, with a view to determining the pre-glacial drainage system of the region.

a) The mode of origin of the three narrows?

b) Which of the three is widest? Narrowest?

c) Work out a pre-glacial drainage system which would account for these gaps.

d) Explain how streams came to flow across the hard rock of the ranges. In answering this, use your answer to question 13.

e) Does the fact that the Devils Lake gap is curved, have any bearing on your conclusion in d)?

15. Note the various passes of drift deposits in the region.

16. Using the terminal moraine, as mapped on Plate CXX of Professional Paper 60 as a beginning, trace the terminal moraine on the maps to the north boundary of the Briggsville sheet on the north, and to the Wisconsin River above Prairie du Sac on the south.

*17. Give the main topographic differences between the area west of the terminal moraine and that to the east.

*18. Does bed-rock or drift control the topography immediately north and east of Merrimac? West of Lodi?

19. Give possible explanations for the small undrained depressions on the outwash plain 3 miles north by northwest of Baraboo. What term is applied to outwash plains with such depressions in their surfaces?

20. Locate an outwash plain on the maps, not shown in Plate CXX of Professional Paper 60.

*21. Bring out the influence of the topography on the position of the edge of the ice during the glacial period.

*22. a) State all the ways in which the direction of the movement of the ice is suggested by the maps.

b) What additional evidence might be found in the field, which is not shown on topographic maps?

*23. Explain the probable origin of Devils Lake.

24. Is there any reason for thinking that Devils Lake was higher during the time of glaciation than now?

25. Compare the altitude of the surface of Devils Lake with that of the Baraboo River at Baraboo, and with that of the Wisconsin River at Merrimac.

26. How must the presence of the ice have affected the Baraboo River?

*27. How could the answer to 26 be tested in the field?

28. Give a possible explanation for the nearly flat land along the Baraboo River between Baraboo and the Baraboo Narrows.

29. The probable origin of the marshes north of the Baraboo Narrows?

*30. Give a rational explanation for the narrowing of the Wisconsin valley at The Dells above Kilbourn. Did the ice probably have anything to do with this?

*31. As a summary of questions 13–30, describe in as much detail as possible the great change in drainage brought about by glaciation.

32. How extensively has the surface of the drift been eroded by streams since is was deposited?

33. What probably becomes of the water which flows into and falls on the surface of Devils Lake, in view of the fact that the lake has no surface outlet?

34. Why are there more houses between Merrimac and the terminal moraine to the west, than in the district around Denzer and Leland?

*35. Note the number of houses along the north-south road leading north from the east edge of Baraboo, and compare with the number along the north-south road leading south from Coon Bluffs (south central part of The Dells Sheet). Explain the difference.

36. Where are the most favorable localities for farming in this region, so far as can be told from your study of the maps?

37. Summarize the events in the history of the region, which may be determined with at least some degree of certainty from a study of the maps. Compared with the data that can be collected in the field and the interpretation of history recorded by these data, the results of the present study are slight.

If further work of the nature of this exercise is desired, it is suggested that the maps of the student's own vicinity or maps of some area in which he is interested be used as a basis. Such maps may be used instead of those mentioned in this exercise. It is not necessary that all students use the same maps, in an exercise of this kind.

XVII. A BRIEF STUDY OF THE PHYSIOGRAPHY OF THE UNITED STATES

This exercise is meant to bring out, so far as is possible from the maps used in this course, the distinctions between the main physiographic provinces of the United States. It must be recognized, however, that no more than an introduction to the subject is attempted, and that the maps used cover only a very small part of each province to be studied.

I. ASSIGNMENT

All the topographic maps used in this course.

Some good map of the United States, showing political boundaries.

A relief map or model of the United States, if available.

II. OUTLINE FOR STUDY

1. The following are the more important provinces of the United States, the divisions being made so far as possible into distinct physiographic units:

1) The Atlantic Coastal Plain.
2) New England and Eastern New York.
3) The Appalachian Mountain Province.
4) The Cumberland-Alleghany Plateau.
5) The Lower Mississippi Basin.
6) The Upper Mississippi Basin.
7) The Great Plains.
8) The Rocky Mountains, including their many ranges.

9) The Sierra Nevada Mountains and other ranges near the Pacific Coast.

10) The Great Basin, including the Southwest Plateau.

2. Using the political and relief maps of the United States mentioned above, arrange all the topographic maps of this course into 10 groups according to the physiographic divisions given in 1.

3. Select two or three sheets which represent, as well as any, the type of topography characteristic of each province.

*4. Using the sheets of 3, and referring to other maps of the ten groups when necessary, describe briefly the main physiographic features of each province, the principal agents and processes which have developed those features, and as nearly as possible the sequence of events in the development of the present surface of each province. This question may be answered without great detail, but only after a thorough study of the maps.

XVIII. EXERCISE FOR REVIEW

* Make as complete an interpretation as possible, of each of the regions shown in the following maps:

Antietam, Md.	Lakin, Kan.
Apishapa, Colo.	Natural Bridge Special, Va.
Bridgeport, Cal.	Passaic, N. J.
Chief Mountain, Mont.	Sallisaw, Ok.
Hawthorne, Nev.	Waterloo, Wis.

ology

LISBURY
Science Se

pp. $4.0
xi+624 p

vey:—I ar
he thoroug
their result
ining styl
the studer
f geologica
spirit whic

Michigan:—
rinciples o
as markin
e science o

tion:—It i
fection, an

(America

ors' widel
for the a

I find it s
I decided t

kansas:—
Geology f

Miss.:—
eology.

HENRY HOLT & CO. 34 West 33d Street, New Yo
378 Wabash Avenue, Chica